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Colorectal Cancer and Mitochondrial Dysfunctions of the Adjunct Adipose Tissues: A Case Study

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Abstract

© 2018 A. P. Burlaka et al. Excess body weight has been causally linked to an increased risk of different cancer types, including colorectal cancer (CRC) but the mechanisms underlying this association are practically unknown. We investigate redox state-superoxide (SO) generation rate, activity of complex I in electron transport chain (ETC) of mitochondria and of dinitrosyl iron complexes by electron paramagnetic resonance; activity of matrix metalloproteinase (gelatinase) MMP-2 and MMP-9 by gel zymography of adipose tissues (AT) from 46 patients (64.0 ± 1.6 y.o.) with CRC (II-III stages, pT2-3N0-2M0) in the AT adjacent to tumor (ATAT) and at a distance of 3 cm from the tumor (ATD) to follow the connection of the AT redox state with some of the tumor microenvironment indicators. We have incubated the AT species with the tumor necrosis factor α (TNF-α) to follow its influence on the measured values. As a control, normal AT (NAT) obtained during the liposuction is used. Tumor-induced changes in mitochondrial ETC of ATAT, particularly for Complex I, lead to the enhanced SO generation and consequent oxidative modifications of DNA in ATAT (up to 6.1 times higher than that in NAT and 3.7 times higher than that in ATD, $p < 0.05$). Gelatinase activity in ATAT is significantly higher than in ATD. A considerable effect of TNF-α on ATAT and ATD (but not on NAT, i.e., only on the tissues where the reprogramming of metabolism has already occurred under the influence of tumor) manifested in increase of cellular hypoxia, gelatinase activity, and SO generation rate is observed. The results can be used for better understanding the mechanism(s) of metabolic symbiosis of tumor and AT as well as serving as a basis for new therapeutic approaches.

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References

[1] J. Ferlay, I. Soerjomataram, R. Dikshit et al., "Cancer incidence and mortality worldwide: sources, methods and major patterns in GLOBOCAN 2012," International Journal of Cancer, 2014.

[2] M. Arnold, M. Leitzmann, H. Freisling et al., "Obesity and cancer: An update of the global impact," Cancer Epidemiology, vol. 41, pp. 8-15, 2016.

[3] G. De Pergola and F. Silvestris, "Obesity as a Major Risk Factor for Cancer," Journal of Obesity, vol. 2013, Article ID 291546, 11 pages, 2013.

[4] B. Lauby-Secretan, C. Scoccianti, D. Loomis, Y. Grosse, F. Bianchini, and K. Straif, "Body fatness and cancer - Viewpoint of the IARC working group," The New England Journal of Medicine, vol. 375, no. 8, pp. 794-798, 2016.

[5] M. Sun, W. Feng, F. Wang et al., "Meta-analysis on shift work and risks of specific obesity types," Obesity Reviews, vol. 19, no. 1, pp. 28-40, 2018.

[6] M. Ng, T. Fleming, M. Robinson, and et al, "Global, regional, and national prevalence of overweight and obesity in children and adults during 1980-2013: a systematic analysis for the Global Burden of Disease Study 2013," The Lancet, vol. 384, no. 9945, pp. 766-781, 2014.

[7] The GBD 2015 Obesity Collaborators, "Health Effects of Overweight and Obesity in 195 Countries over 25 Years," The New England Journal of Medicine, vol. 377, no. 1, pp. 13-27, 2017.

[8] I. Vučenik, J. P. Stains, and L. P. Jones, "The relationship between obesity and cancer," Periodicum biologorum, vol. 116, no. 4, pp. 347-353, 2014.

[9] E. Lengyel, L. Makowski, J. DiGiovanni, and M. G. Kolonin, "Cancer as a Matter of Fat: The Crosstalk between Adipose Tissue and Tumors," Trends in Cancer, vol. 4, no. 5, pp. 374-384, 2018.

[10] I. Vucenik, L. P. Jones, and J. C. McLenithan, Linking Obesity, Metabolism and Cancer. Metabolic Syndrome: A Comprehensive Textbook, 1-21, 2014.

[11] S. Havermann, C. Büchter, K. Koch, and W. Wätjen, "Role of oxidative stress in the process of carcinogenesis," Studies on Experimental Toxicology and Pharmacology, pp. 173-198, 2015.

[12] C. Cerdá, C. Sánchez, B. Climent et al., "Oxidative Stress and DNA Damage in Obesity-Related Tumorigenesis," in Oxidative Stress and Inflammation in Non-communicable Diseases-Molecular Mechanisms and Perspectives in Therapeutics, vol. 824 of Advances in Experimental Medicine and Biology, pp. 5-17, Springer International Publishing, Cham, 2014.

[13] S. Reuter, S. C. Gupta, M.M. Chaturvedi, and B. B. Aggarwal, "Oxidative stress, inflammation, and cancer: how are they linked?" Free Radical Biology & Medicine, vol. 49, no. 11, pp. 1603-1616, 2010.

[14] L. R. De Lope, O. L. Alcíbar, A. A. López, M. Hergueta-Redondo, and H. Peinado, "Tumour-adipose tissue crosstalk: Fuelling tumourmetastasis by extracellular vesicles," Philosophical Transactions of the Royal Society B: Biological Sciences, vol. 373, no. 1737, 2018.

[15] L. Marseglia, S. Manti, G. D'Angelo et al., "Oxidative stress in obesity: a critical component in human diseases," International Journal of Molecular Sciences, vol. 16, no. 1, pp. 378-400, 2014.

[16] R. Divella, R. De Luca, I. Abbate, E. Naglieri, and A. Daniele, "Obesity and cancer: The role of adipose tissue and adipocytokines-induced chronic inflammation," Journal of Cancer, vol. 7, no. 15, pp. 2346-2359, 2016.

[17] B. Halliwell and J. M. C. Gutteridge, Free radicals in biology andmedicine, Oxford University Press, Oxford, UK, 5th edition, 2015.

[18] B. Schwartz and E. Yehuda-Shnaidman, "Putative role of adipose tissue in growth and metabolism of colon cancer cells," Frontiers in Oncology, vol. 4, 2014.

[19] S. Crotti, M. Piccoli, F. Rizzolio, A. Giordano, D. Nitti, and M. Agostini, "Extracellular Matrix and Colorectal Cancer: How Surrounding Microenvironment Affects Cancer Cell Behavior?" Journal of Cellular Physiology, vol. 232, no. 5, pp. 967-975, 2017.

[20] A. Tarasiuk, P. Mosinska, J. Fichna, and P. Mosińska, "The mechanisms linking obesity to colon cancer: An overview," Obesity research clinical practice, vol. 2, no. 3, pp. 251-259, 2018.

[21] I.G. Shabalina, M. Vrbacký, A. Pecinová et al., "ROSproduction in brown adipose tissue mitochondria: The question of UCP1-dependence," Biochimica et Biophysica Acta (BBA) - Bioenergetics, vol. 1837, no. 12, pp. 2017-2030, 2014.

[22] S. S. Sabharwal and P. T. Schumacker, "Mitochondrial ROS in cancer: initiators, amplifiers or an Achilles' heel?" Nature Reviews Cancer, vol. 14, no. 11, pp. 709-721, 2014.

[23] R. G. Saifutdinov, L. I. Larina, T. I. Vakul'skaya, and M. G. Voronkov, Electron Paramagnetic Resonance in Biochemistry and Medicine, Springer, NY, USA, 2001.

[24] S. C. Kazmierczak, A. Gurachevsky, G. Matthes, and V. Muravsky, "Electron spin resonance spectroscopy of serum albumin: a novel newtest for cancer diagnosis and monitoring," Clinical Chemistry, vol. 52, no. 11, pp. 2129-2134, 2006.

[25] A. P. Burlaka, I. I. Ganusevich, S.N. Lukin, M. R. Gafurov, and E. P. Sidorik, "Superoxide-and NO-Dependent Mechanisms of the Reprogramming of Bone Marrow Cells by Tumor Cells," Applied Magnetic Resonance, vol. 45, no. 11, pp. 1261-1273, 2014.

[26] S. Mrakic-Sposta, M. Gussoni, M. Montorsi, S. Porcelli, and A. Vezzoli, "A Quantitative Method to Monitor Reactive Oxygen Species Production by Electron Paramagnetic Resonance in Physiological and Pathological Conditions," Oxidative Medicine and Cellular Longevity, vol. 2014, Article ID 306179, 10 pages, 2014.

[27] A. Burlaka, M. Selyuk, M. Gafurov, S. Lukin, V. Potaskalova, and E. Sidorik, "Changes in mitochondrial functioning with electromagnetic radiation of ultra high frequency as revealed by electron paramagnetic resonance methods," International Journal of Radiation Biology, vol. 90, no. 5, pp. 357-362, 2014.

[28] A. P. Burlaka, A. V. Vovk, A. A. Burlaka, M. R. Gafurov, K. B. Iskhakova, and S. N. Lukin, "Rectal Cancer: Redox State of Venous Blood and Tissues of Blood Vessels from Electron Paramagnetic Resonance and Its Correlation with the Five-Year Survival," BioMed Research International, vol. 2018, Article ID 4848652, 7 pages, 2018.

[29] A. P. Burlaka, I. I. Ganusevich, M. R. Gafurov, S. M. Lukin, and E. P. Sidorik, "Stomach cancer: interconnection between the redox state, activity of MMP-2, MMP-9 and stage of tumor growth," Cancer Microenvironment, vol. 9, no. 1, pp. 27-32, 2016.

[30] A. P. Burlaka, M. R. Gafurov, K. B. Iskhakova et al., "Electron paramagnetic resonance in the experimental oncology: implementation examples of the conventional approaches," Bio Nano Science, vol. 6, no. 4, pp. 431-436, 2016.

[31] K. E. Prosser and C. J. Walsby, "Electron Paramagnetic Resonance as a Tool for Studying the Mechanisms of Paramagnetic Anticancer Metallodrugs," European Journal of Inorganic Chemistry, vol. 2017, no. 12, pp. 1573-1585, 2017.

[32] S. I. Dikalov, V. I. Mayorov, and A. V. Panov, "Physiological levels of nitric oxide diminish mitochondrial superoxide. Potential role of mitochondrial dinitrosyl iron complexes and nitrosothiols," Frontiers in Physiology, vol. 8, 2017.

[33] S. B. Lohan, S. Ahlberg, A. Mensch et al., "EPR Technology as Sensitive Method for Oxidative Stress Detection in Primary and Secondary Keratinocytes Induced by Two Selected Nanoparticles," Cell Biochemistry and Biophysics, vol. 75, no. 3-4, pp. 359-367, 2017.

[34] R. Krzyminiewski, B. Dobosz, and T. Kubiak, "The influence of radiotherapy on ceruloplasmin and transferrin in whole blood of breast cancer patients," Radiation and Environmental Biophysics, vol. 56, no. 4, pp. 345-352, 2017.

[35] A. Burlaka, A. Vovk, A. Burlaka et al., "Redox Status of a Metastatic Microenvironment in the Liver of Patients with Colorectal Cancer from EPR," Applied Magnetic Resonance, In press.

[36] K. M. Nieman, I. L. Romero, B. van Houten, and E. Lengyel, "Adipose tissue and adipocytes support tumorigenesis and metastasis," Biochimica et Biophysica Acta (BBA)-Molecular and Cell Biology of Lipids, vol. 1831, no. 10, pp. 1533-1541, 2013.

[37] C. Gialeli, A. D. Theocharis, and N. K. Karamanos, "Roles of matrix metalloproteinases in cancer progression and their pharmacological targeting," FEBS Journal, vol. 278, no. 1, pp. 16-27, 2011.

[38] K. Kessenbrock, V. Plaks, and Z. Werb, "Matrix metalloproteinases: regulators of the tumor microenvironment," Cell, vol. 141, no. 1, pp. 52-67, 2010.

[39] A. P. Burlaka, E. P. Sidorik, I. I. Ganusevich, and S. P. Osinsky, "Effects of radical oxygen species and NO: formation of intracellular hypoxia and activation of matrix metalloproteinases in tumor tissues," Exp Oncol, vol. 28, no. 1, pp. 49-53, 2006.

[40] A. P. Burlaka, E. P. Sidorik, I. I. Ganusevich, Y. M. Lestchenko, A. A. Burlaka, and S. P. Osinsky, "High formation of superoxide anion and nitric oxide, and matrix metalloproteinases activity in vascular wall of rectal carcinoma vessels," Exp Oncol, vol. 28, no. 4, pp. 323-325, 2006.

[41] G. Derosa, I. Ferrari, A. D'Angelo et al., "Matrix Metalloproteinase-2 and -9 Levels in Obese Patients," Endothelium-Journal of Endothelial Cell Research, vol. 15, no. 4, pp. 219-224, 2008.

[42] E. C. M. Mariman and P. Wang, "Adipocyte extracellular matrix composition, dynamics and role in obesity," Cellular and Molecular Life Sciences, vol. 67, no. 8, pp. 1277-1292, 2010.

[43] A. P. Burlaka, I. I. Ganusevich, A. V. Vovk, V. V. Golotiuk, and S. M. Lukin, "Redox-dependent mechanisms of inflammation in adipose tissue of patients with rectal cancer," Onkologia, vol. 18, no. 3, pp. 204-209, 2016.

[44] S. Dikalov, M. Skatchkov, and E. Bassenge, "Spin trapping of superoxide radicals and peroxynitrite by 1-hydroxy-3-carboxy-pyrrolidine and 1-hydroxy-2,2,6,6-tetramethyl-4-oxopiperidine and the stability of corresponding nitroxyl radicals towards biological reductants," Biochemical and Biophysical Research Communications, vol. 231, no. 3, pp. 701-704, 1997.

[45] G. Liou and P. Storz, "Reactive oxygen species in cancer," Free Radical Research, vol. 44, no. 5, pp. 479-496, 2010.

[46] K. C. Kim and C. H. Lee, "MAP kinase activation is required for the MMP-9 induction by TNF-stimulation," Archives of Pharmacal Research, vol. 28, no. 11, pp. 1257-1262, 2005.

[47] C.-L. Tsai, W.-C. Chen, H.-L. Hsieh, P.-L. Chi, L.-D. Hsiao, and C.-M. Yang, "TNF-α induces matrix metalloproteinase-9-dependent soluble intercellular adhesion molecule-1 release via TRAF2-mediated MAPKs and NF-κB activation in osteoblastlike MC3T3-E1 cells," Journal of Biomedical Science, vol. 21, no. 1, article no. 12, 2014.

[48] M. Steenport, K. M. F. Khan, B. Du, S. E. Barnhard, A. J. Dannenberg, and D. J. Falcone, "Matrix metalloproteinase (MMP)-1 and MMP-3 induce macrophage MMP-9: evidence for the role of TNF-α and cyclooxygenase-2," The Journal of Immunology, vol. 183, no. 12, pp. 8119-8127, 2009.

[49] L. De Groef, M. Salinas-Navarro, G. Van Imschoot, C. Libert, R. E. Vandenbroucke, and L. Moons, "Decreased TNF Levels and Improved Retinal Ganglion Cell Survival in MMP-2 Null Mice Suggest a Role for MMP-2 as TNF Sheddase," Mediators of Inflammation, vol. 2015, 2015.